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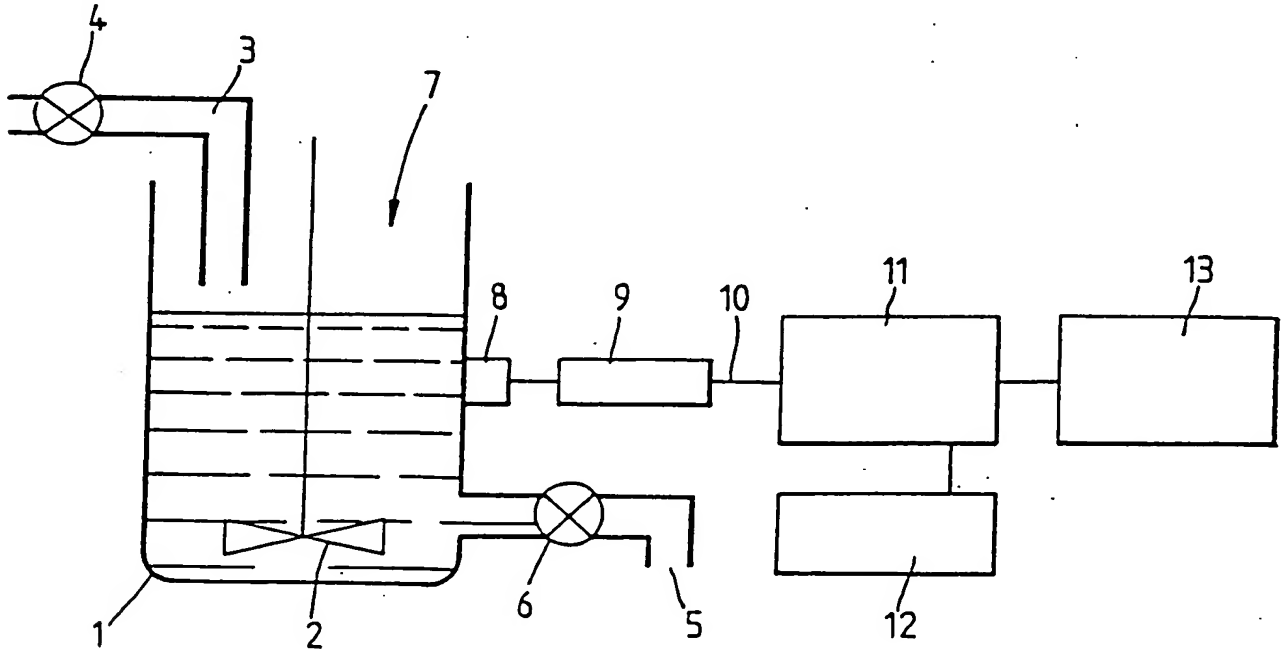
(54) Monitoring of process steps

(57) Apparatus for monitoring the performance of one or more steps in a process includes a sensor 8 for sensing sounds emanating in the course of the process and for producing an electrical signal representing the frequency spectrum of the sounds, at least two band pass filters 11 for separating from the electrical signal the components representing sounds within at least two different frequency bands, and means for deriving an output signal representing the ratio or the difference of the intensities of the components. The output signal 13 is compared with known criteria of the step to give an indication of, for example, satisfactory completion of the step.



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The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy

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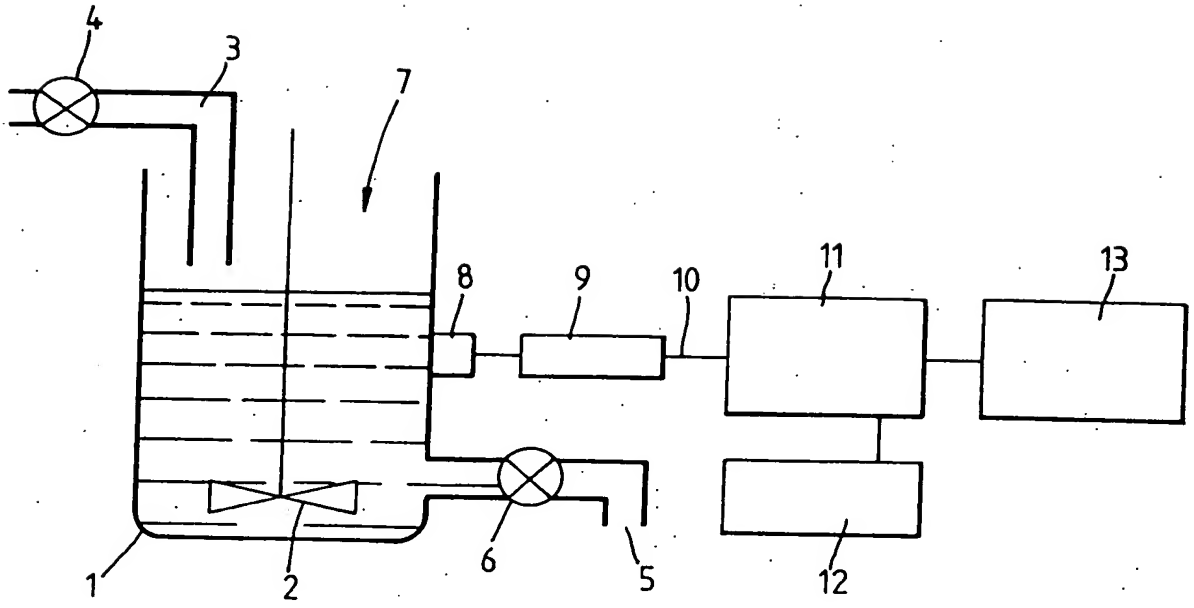
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SPECIFICATION

Monitoring of process steps

This invention relates to the monitoring of process steps in order to provide confirmation that a particular one or more process steps have taken place as intended. The invention can be applied to process steps in a wide variety of industrial processes, and to a wide variety of steps in such processes. In an automated plant such process steps or operations are usually assumed to actually take place on powering the appropriate actuator. However if for reasons of an undetected fault the operation is not completed, financial loss or even danger to life can result. It is possible to equip each item in a plant with a validation sensor which may confirm for example that a valve has opened or a heater has turned on. This increases complexity, cost and maintenance requirements, and would not check for instance if flow actually had taken place on opening the valve, or that the heater was actually performing its intended function.

There thus exists a need for devices which will actually confirm that a variety of different kinds of process step have taken place as intended, so that any necessary remedial action can be taken as quickly as possible. For practical reasons it is preferable that any such device intrudes as little as possible into the working environment of the process so as to avoid interference therewith and facilitate maintenance. Any such device should also preferably be simple in construction and use, inexpensive, reliable and inherently safe.

The present invention seeks to provide an apparatus and a method for the monitoring of process steps which can meet as many as possible of these objectives.

Accordingly the present invention provides apparatus for monitoring the performance of one or more steps in a process, the apparatus comprising a sensor for sensing sounds emanating in the course of the process and for producing an electrical signal representative of the frequency spectrum of the said sounds, at least two band pass filters for separating from the said electrical signal the components thereof representative of sounds within at least two different frequency bands, and means for deriving an output signal representing the ratio or the difference of the intensities of the said components.

The term "sound" as used herein includes sounds in the audible range as well as the ultrasonic range.

The apparatus can be designed to monitor a very wide range of process steps which are characterised by the emission of sound, including for example the addition of solid to a mix, opening or closure of a valve and the consequent changes in flow of materials therethrough, boiling, stirring, crystallising, switching, or discharging of materials.

In most cases it is found that best results are obtained with a sensor which functions in the ultrasonic range of frequencies, although in some cases a sensor operative in the audible range may be more suitable. This will depend upon the nature of the process steps being monitored.

The sensor will plainly need to have some form of accoustic coupling with the working medium of the process being monitored. In most cases this can be provided by placing the sensor in close proximity or in contact with some part of the apparatus in which the process is performed, and reliance can be placed, if necessary, on the transmission of sounds from the point where the process step is performed through the working medium or the process apparatus. It is unlikely to be necessary for the sensor to be placed in direct contact within the working medium.

A single sensor can thus if desired provide the signals necessary for monitoring a number of process steps occurring at different locations within a process apparatus.

Alternatively, two or more sensors can be used in differing parts of a plant to increase sensitivity to a particular process step or reduce interfering noise.

The invention rests on the realisation that each process step will give rise to a unique sound signature indicative of its performance. In many processes, especially industrial processes there may be a high level of background noise (eg the presence of high pressure steam injection), which on the normal way would tend to mask this signature so as to render it unrecognisable.

By forming the ratio or difference of intensities in two different frequency bands, however, the Applicant has shown that a positive and reliable indication can be provided.

The apparatus of the invention may include a validation device for comparing the said output signal with a signal of predetermined form or magnitude representative of the desired performance of a process step, and to provide an alarm signal if the output and predetermined signals differ by more than a predetermined value.

Where it is desired to monitor a plurality of different process steps, the validation device may include means for comparing the output signal with a corresponding plurality of signals of predetermined form or magnitude, each being representative of the desired performance of an individual proces step.

In this case, the validation device may also be such as to provide an alarm signal if the output signals are not provided in a predetermined sequence.

The apparatus may include a visual or audible alarm which can be triggered by the alarm signal, or a visual or electronic recording device driven by the alarm signal, or may

include means for automatically stopping the process in response to an alarm signal.

According to another aspect of the invention, there is provided a method of monitoring the performance of one or more steps in a process, the method comprising the steps of sensing the sounds emanating in the course of the process; producing an electrical signal representative of the frequency spectrum of the said sounds; separating from the said electrical signal the components thereof representative of sounds within two different frequency bands; and deriving an output signal representing the ratio or the difference of the intensities of the said components.

The invention will now be described by way of example only, with reference to the accompanying drawing, which is a simple diagramatic representation showing how the invention may be applied to a simple process.

As shown in the figure, a process to be monitored is carried out in a vessel 1 containing a stirrer 2 and provided with an inlet pipe 3 having a control valve 4, and an outlet pipe 5 having a control valve 6. Solid material can be added to the vessel through its open top, as indicated by the arrow at 7.

Apparatus in accordance with the invention for monitoring the process performed in the vessel 1, so as to provide positive confirmation when each process step is carried out, comprises an ultrasonic sensor 8, which as illustrated is clamped firmly to the surface of the vessel 1. This arrangement is best suited to the sensing of higher frequency ultrasound, whereas for the detection of lower frequency audible emissions, the sensor could be placed close to the vessel 1 with air as the coupling medium.

The sensor 8 provides an electrical signal representative of the frequency spectrum of ultrasonic sounds emanating from the vessel 1 during the course of the process being performed therein. More than one sensor 8 may be provided if desired (eg to monitor for both audible and ultrasonic sounds).

The electrical signal from the sensor 8 is amplified in a pre-amplifier 9, and is then transmitted by means of a cable 10 (which may be of any desired length) to an electronic processing unit 11.

The processing unit 11 includes a number a number of band pass filters. Two are used for each process step to be monitored. The same pair or another pair may be used for the next step and so on through the process sequence. Where two or more sensors are used, their outputs will be monitored concurrently and frequencies selected as required by each process step.

For each respective pair of band pass filters the processing unit forms an output signal representing a ratio (or normally less suitably, a difference) of the intensities of the signal components passed by the two filters concerned. This output is compared in the processing unit 11 with a predetermined pattern characteristic of the intended sequence of steps in the process being monitored. If the comparison shows an undue discrepancy, then this is taken as an indication that an intended process step has not taken place, and the processing unit produces an alarm signal, which can be supplied to an alarm unit 12 which may actuate an audible or visual alarm, or may automatically half the process.

Alternatively or additionally, the processing unit 11 may provide signals to a visual or electronic recording device 13, such as a chart recorder, which records output signals indicative of correct functioning of the process.

As illustrated the process performed in the vessel 1 might, as an example, comprise a sequence of process steps as follows:

i) Open valve 4 to admit a fluid to the vessel 1 until it reaches the level of tube 3. One pair of band pass filters are selected so as to monitor a characteristic sound created by fluid pouring into the vessel, and the same or another pair to monitor for the sound characteristic of submergence of the end of the tube 3.

ii) Start the stirrer 2. The same or a different frequency pair of band pass filters may be used to monitor for this.

iii) Add batches of solid material at 7. The same or a different frequency pair of filters may be used here also.

iv) After a predetermined time from the addition of solid, stop the stirrer and open the valve 6. Here again, the same or a different frequency pair of filters may be used to monitor this step.

The cycle can then repeat automatically when the batch process restarts.

Naturally the monitoring apparatus can be adapted for process steps of many other kinds without departing from the scope of the invention, as will be apparent to those skilled in the art–.

CLAIMS

1. Apparatus for monitoring the performance of one or more steps in a process, the apparatus comprising a sensor for sensing sounds emanating in the course of the process and for producing an electrical signal representative of the frequency spectrum of the said sounds, two band pass filters for separating from the said electrical signal the components thereof representative of sounds within two different frequency bands, and means for deriving an output signal representing the ratio or the difference of the intensities of the said components.

2. Apparatus according to claim 1 and specially adapted to monitor one or more process steps selected from the group comprising addition of solid to a mix, opening or

closure of a valve or the consequent changes in flow of materials therethrough, boiling, stirring, crystallising, switching, or discharging of material.

3. Apparatus according to claim 1 or claim 2 wherein a single sensor provides the signals necessary for monitoring a number of process steps occurring at different locations within a process operation.

4. Apparatus according to any one preceding claim and including a plurality of sensors at different locations.

5. Apparatus according to any one preceding claim and including a validation device for comparing the said output signal with a signal of predetermined form or magnitude representative of the desired performance of a process step, and for providing an alarm signal if the output and predetermined signals differ by more than a predetermined value.

6. Apparatus according to claim 5 for monitoring a plurality of different process steps, wherein the validation device includes means for comparing the output signal with a corresponding plurality of signals of predetermined form or magnitude, each being representative of the desired performance of an individual process step.

7. Apparatus according to claim 6 wherein the validation device is such as to provide an alarm signal if the output signals are not provided in a predetermined sequence.

8. Apparatus according to claim 7 and including a visual or audible alarm which can be triggered by the alarm signal, or a visual or electronic recording device driven by the alarm signal, or may include means for automatically stopping the process in response to an alarm signal.

9. A method of monitoring the performance of one or more steps in a process, the method comprising the steps of sensing the sounds emanating in the course of the process; producing an electrical signal representative of the frequency spectrum of the said sounds; separating from the said electrical signal the components thereof representative of sounds within two different frequency bands; and deriving an output signal representing the ratio or the difference of the intensities of the said components.

10. Apparatus for monitoring the performance of one or more steps in a process according to claim 1 and substantially as hereinbefore described.

11. A method of monitoring the performance of one or more steps in a process according to claim 9 and substantially as hereinbefore described.

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